ARTIFICIALLY ESTABLISHED
WHITE PINE PLANTATIONS IN MINNESOTA:
A SURVEY

A Plan B Paper

by

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INTRODUCTION

The reestablishment and regeneration of white pine in Minnesota has been greatly limited or ignored due to the fear of damage from white pine blister rust and white pine weevil. White pine is still in strong demand for many products, has favorable growth rates and high yields on suitable sites, can grow well on poor hardwood sites where no other species is suitable, and is becoming an increasingly important species in the eyes of the public. There is, recently, strong interest in regenerating white pine among forest management agencies in the State. White pine can still be a profitable and highly desirable species to manage with proper planning for pest management in plantation establishment.

This report describes the major damaging agents to white pine in Minnesota, factors influencing damage, and the associated control measures. It consists of a literature review, the results of a survey of forest management agencies, and a report of observations of white pine plantations throughout Minnesota.

STUDY OBJECTIVES

The objective of this study survey research is to identify and suggest conditions, techniques and sites that are compatible with successful establishment and development of white pine plantations in Minnesota.

The following parameters were examined in the field to determine their impact on white pine plantation establishment:

1. white pine blister rust
2. white pine weevil
3. white-tailed deer
4. presence of Ribes in the stand
5. distance from bodies of water
6. age of trees
7. topography and aspect
8. underplanting existing stands
9. pathological pruning

LITERATURE REVIEW

The literature review focuses on the major damaging agents to white pine plantations, factors influencing damage and their associated control.

Damaging Agents

The primary damaging agents are white pine blister rust, white pine weevil and white-tailed deer.

White Pine Blister Rust

The blister rust disease is caused by a fungus, Cronartium ribicola J.C. Fisher ex Rabenh. The fungus was introduced into the United States (New York), from imported German seedlings, in 1908. The disease spread and reached Minnesota around 1916.

The disease goes through five spore stages and utilizes two hosts, to complete it's life cycle (Figure 1). The two hosts are Ribes spp. (currents and gooseberries) and white pine. Windblown basidiospores from the Ribes germinate and infect the pine needles in late summer and early fall. In Minnesota, August is the most important month for blister rust infection. The disease requires low temperatures and high moisture for germination and infection. Once the needles are

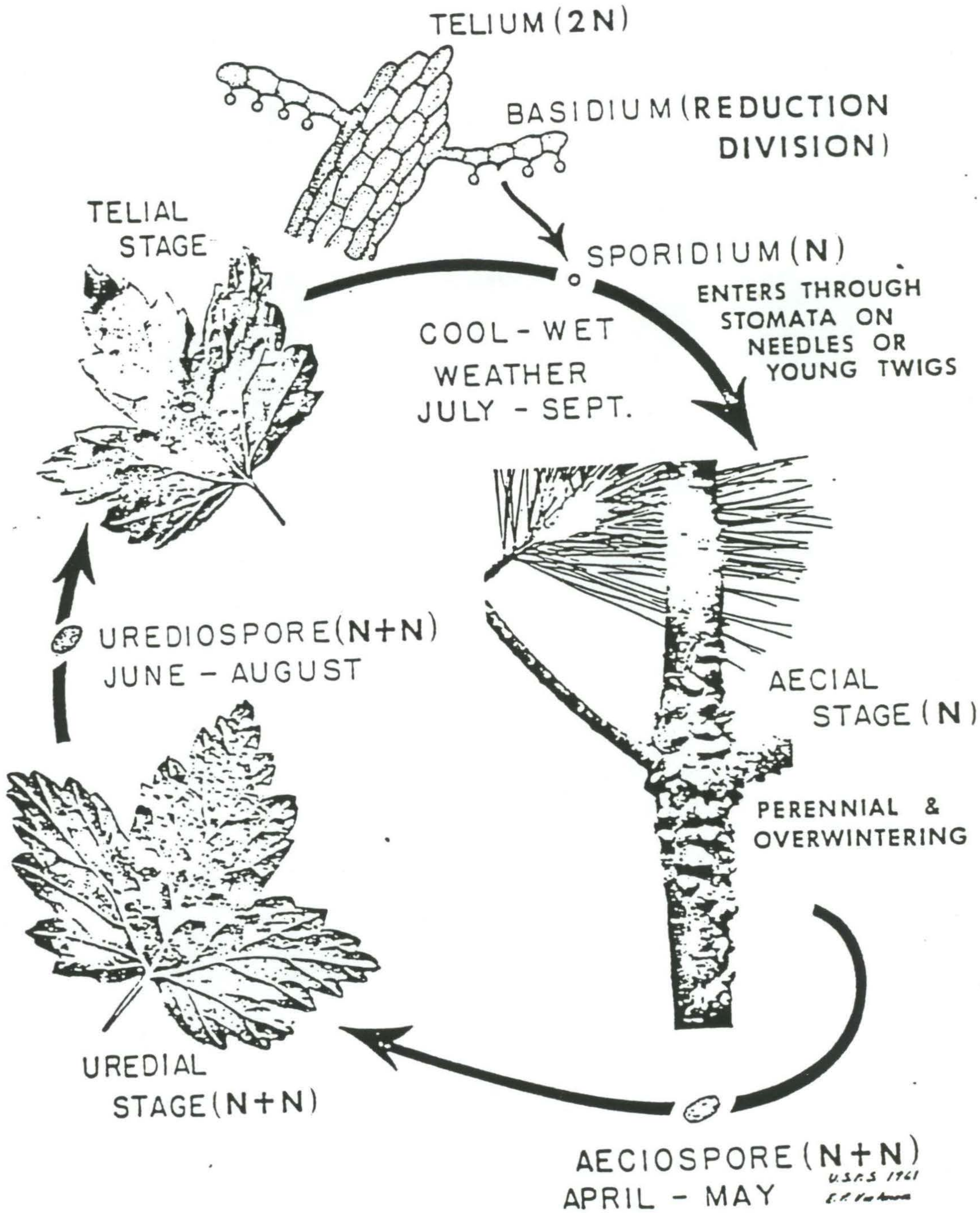

Figure 1. Life cycle of Cronartium ribicola (Taken from E.P. Van Arsdel 1979).

infected, mycelium grows into the bark of the twigs, branches, and eventually into the main stem.

The fungus penetrates the bark 12 to 18 months after infection. Aeciospores produced in the spring, 3 to 6 years after infection, are then windblown to the Ribes leaves. The spores germinate on the undersides of the leaves and produce urediospores within 7 to 18 days. In a few weeks, teliospores are produced and germinate in the fall to produce basidiospores (sporidia). The basidiospores are released at night and are windblown to the pine needles, completing the life cycle.

The mycelium and aecia production in the bark can cause mortality by girdling the main stem. Seedlings and saplings are killed rapidly while larger trees die slower. Infections in larger trees can be lethal, but often just kills branches and tops of trees above the point of stem infection. Recent studies in the Lake States (Mielke et.al. 1990 and 1989; Robbins et.al. 1988), show less rust infection than expected, based on Van Arsdels' (1964) hazard zones.

White Pine Weevil

The white pine weevil, Pissodes strobi (Peck), is the most important insect pest of the white pine. This native insect increased in numbers and damage as a result of land abandonment starting in the 19th century. Land abandonment led to an increase in open-grown pure white pine stands and also provided other favorable conditions for the pest insect.

Winter is spent in the adult stage in the soil litter layer. Adults emerge from March to May, depending on locality, and feed on the succulent growth of the terminal leaders, usually on the bark about 7 to 10 inches below the dormant buds (Baker 1972). Eggs are oviposited in the bark on last year's leader and hatch in a week to 10 days. The young larvae bore downwards side by side in a ring, feeding on the phloem of last year's and the previous year's leader. Full growth may be attained before the next whorl of branches is reached, but in some instances, the larvae may pass below the fourth whorl before reaching full development. By late July and August, they become full-grown and pupate in woody chip cocoons formed in the xylem or pith. The young adults emerge in 10 to 15 days and feed on the bark of the terminals for a short time before dropping to the ground litter to overwinter.

The majority of the damage occurs as a result of larval feeding. The larval feeding in the early summer months kills the leading terminal, and effectively destroys 2- to 5-years of vertical growth. The terminal growth of the tree is resumed by one or more of the highest surviving lateral branches. The death of the terminal has a 2- to 3-year effect (Fowells 1965). The result is crooked, forked or multiple stemmed leaders.

The result in either case is a deformed bole reducing height growth, recoverable volume, value for lumber and aesthetics. The wood, both above and below the crook in the bole, is heavily compressed reaction wood. There is also an increase in encased knots, wane, and fungus development. Studies in New Hampshire showed an estimated volume loss of 40 percent in the sawlog portion of sawtimber trees and 70 percent loss in the portion above sawlog limits of merchantability. The average volume loss in pole-size trees was 13 percent (Waters et al 1955). Small pines may be girdled and killed from adult feeding on the terminals, however this damage is less severe and less frequent. The dead terminals ultimately become infection courts for red rot caused by _Fomes pini_ (Thore) Lloyd (Ostrander and Foster 1957). Weevil damage is most crucial economically when the pine is forming the valuable first 16-foot log length.

White-tailed Deer

The white-tailed deer (_Odocoileus virginianus_) can be a serious damaging agent to white pine regeneration. Mortality caused by heavy deer browse is becoming an increasing deterrent to planting white pine in many areas. Damage occurs when terminal and lateral buds are browsed, leaving the tree with no new growth. The loss of the terminal results in crooked, forked or multiple stemmed trees. The end result is a loss of growth, product value and aesthetics value. Repeated browsing can cause mortality in newly planted seedlings under otherwise favorable growing conditions. Damage may also occur from the rubbing of antlers on the stem. Studies by Mielke et al (1990 and 1989) have shown that deer damage is the primary limiting factor in the establishment of white pine in the Superior and Chippewa (MN), Nicolet and Chequamegon (WI), and Ottawa (MI) National Forests.

Factors Influencing Damage

Research in the past has determined soils, climatic conditions, topography and stand characteristics that are associated with decreased damage and increased growth in white pine (Robbins 1984).

Soils

White pine can be grown on nearly every soil within Minnesota, with heavy clayey soils being the exceptions. Performance and problems associated with establishing white pine on specific soils have been noted by several authors (Lutz et al 1947; Scott 1958; Horton and Bedell 1960; Lancaster and Leak 1978; Scott 1983; Robbins 1984; Stiell 1985). The soils for best growth are loams, sandy loams, and fine sands. However, increasing productivity of the site for white pine is associated with increasing productivity of other species as well. During the initial 5-year slow growth period of white pine, competition from hardwoods and other woody vegetation is an important factor. Over a rotation, white pine will outgrow hardwoods on poor and good sites, but it is difficult and costly on good sites.

Hardwood competition is greatest on the richer, moister soils such as loams, sandy loams, stony loams, and glacial till with good or impeded drainage. Competition subsides on poorer hardwood sites with lighter soils such as excessively drained and well drained sands, and droughty, loamy sands. Planting in abandoned fields may be a way to take advantage of the more productive soils, if hardwood succession is not advanced.

Lancaster and Leak (1978) suggest that there is a breaking point between "strong hardwood land" and "strong pine land" around a site index of 55 to 65 for hardwoods. Above this breaking point one should manage for hardwoods, and below manage for pine.

Site conditions may also affect weevil susceptibility (White 1960). Connola and Wixson (1963) found that white pine can be grown with a minimum of weevil damage when the soil mottling and/or hardpan are not present to a depth of 3 feet. Weevil outbreaks frequently occur in stands growing on dry or poorly drained soils, or on sites that have suffered compaction, erosion, or nutrient deficiencies (Berryman 1986).

Climatic Conditions

Climate largely determines the distribution of blister rust in Minnesota. Both large-scale and small-scale climatic factors influence pest damage. Large-scale climatic factors include temperature, moisture and air movements. Small-scale factors are affected by topography and stand characteristics.

Van Arsdel (1961) found that two weeks of cool temperatures (no 3 days more than 82°F--28°C) are required before teliospores will germinate. Germination, formation of basidiospores and infection by these spores requires 48 hours of a saturated atmosphere and a temperature of less than 68°F (28°C). Without the presence of free moisture, usually dew, on the needle surfaces and the low temperatures, germination and infection will not occur. Rust is more prevalent at high elevations and scarce in broad river valleys (Van Arsdel et.al. 1957).

Air movements also influence the spread and travel distance of these spores. Night breezes over land from bodies of water can carry viable basidiospores for several miles affecting the location of differing levels of infection. Air masses over land cool more rapidly at night than over water. The cool air then flows from land to water. This forces the warmer air over the water upward then back over the land as a countercurrent. This countercurrent can come down to the land surface several miles inland. Here infection can be great with less infection closer to the water body.

Considering the probability of favorable temperature and moisture with the influences of elevation and air movements on infection, Van Arsdel (1979) divided the State into four blister rust hazard zones (Figure 2). This hazard zone map indicates the relative risk of rust infection. Hazard zones range from very low risk (Zone 1) in the southern region, to very high risk (Zone 4) in the northern areas. Van Arsdel (1979) stated that not all the details of climatic zoning can be shown on a map of this scale. In southern Minnesota all the lower and broader valleys are in Zone 1; the highest hills and plateaus are in Zone 3; the remainder of the land is in Zone 2. In Zones 3 and 4, in the northern part of the State, any place with more than 1/4 of the trees infected in the tops of the tallest trees should have a hazard level of 4, those without are in Zone 3. These zones are broad and not hard-lined, and there can be great variation of damage within and between zones.

Damage by weevil also varies by geographic zones. The University of Toronto in collaboration with the Forest Insect and Disease Unit at Sault Ste. Marie is developing a hazard rating system for weevil infestation on jack pine; a similar rating system has not been done for white pine in Minnesota. Weevil damage boundaries

Blister Rust Hazard Zones

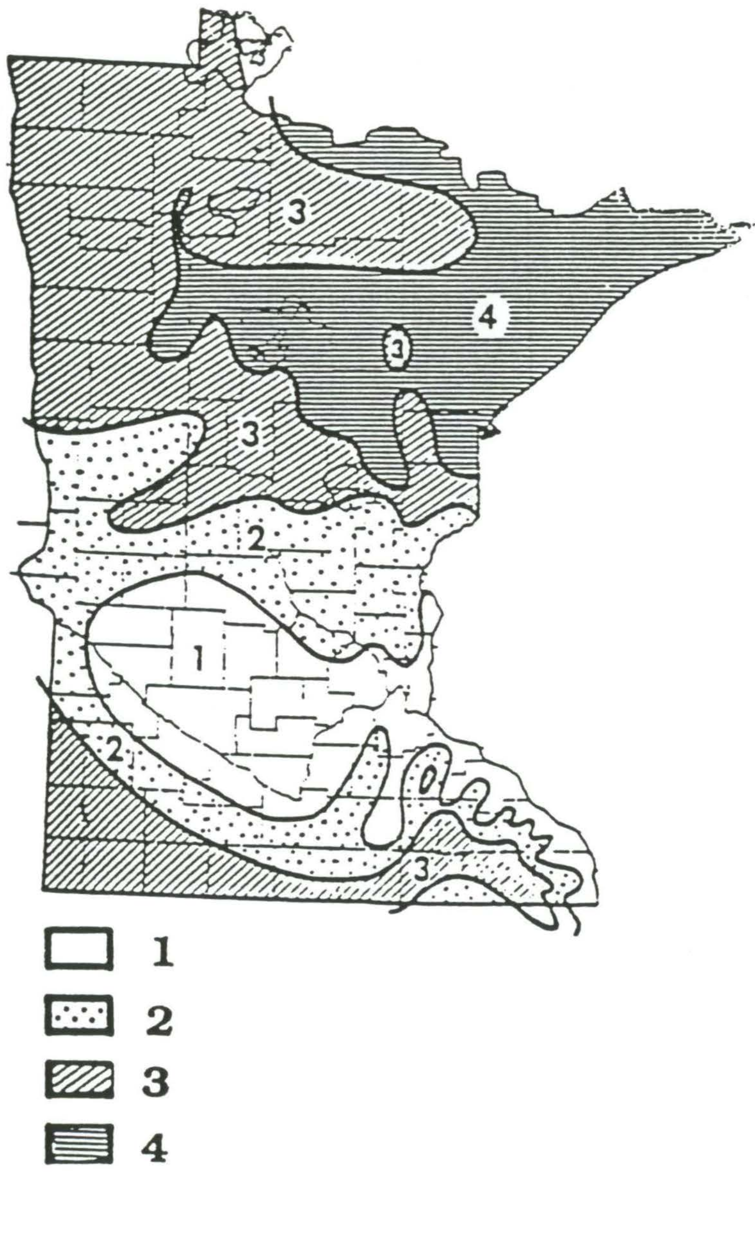

Figure 2. Blister rust hazard zones
(Taken from E.P. Van Arsdel 1979).

are not well defined and vary greatly location to location. However, weevil damage is greater in the northern part of Minnesota than in the southern part.

Small differences in climatic conditions can greatly influence pest damage. These small-scale, microclimatic, conditions are affected by topography and stand characteristics.

Topography

Topography is a feature that accounts for local variations in the microclimate which influences pest damage.

The effect of topography, for blister rust infection, is greatest during clear, cool, windless nights that favor dew formation. Risk of rust infection is more pronounced at the bases of slopes, in small narrow valleys, and in depressions, where cool night air flows downward and accumulates. The cold air flows away from the top and shoulders of hills, making these areas warmer and dried, resulting in less infection.

A dense belt of vegetation running across an otherwise open slope will impede the downslope air flow. Cool air will accumulate on the upslope side of the belt creating a favorable environment for infection.

North-facing slopes are also colder due to less intense solar radiation exposure of shorter duration. However, plantations on the south and west-facing slopes, where light intensity and/or moisture stress is greater, are prone to weevil damage.

Stand Characteristics

Vegetation and plantation size affect the microclimate. Van Arsdel (1964) stated that small openings in the crown canopy with a diameter less than the height of the surrounding trees are cold and moist, and this in turn, favors rust infection. In this situation, direct radiation does not reach the bottom of the opening due to the shading. Temperatures are lower day and night with no direct input of heat energy and continuous outward radiation of heat. With the continuous outward radiation, pine needles may cool below the dew point of the ambient air forming dew, regardless of the relative humidity. The cool moist air draining into the opening from the tops of the surrounding tree canopy can add additional quantities of moisture to the air in the opening. A forest opening with a diameter greater than the height of the surrounding trees is warmer by day and cooler by night, and there is less moisture on the needle surfaces for a shorter duration.

Open-grown trees with full sunlight, however, are more susceptible to weevil attack than shaded trees according to Wilson (1977). The weevil thrives on thick-barked, vigorous shoots of white pine that are growing rapidly in the sunshine (Logan 1966; Sullivan 1961).

Large open plantations may incur less damage by deer because they prefer to browse on forest edges near the overstory cover.

Risk from injury from both rust and weevil is smallest when white pine is planted under an overstory of a light crowned species such as aspen or birch. Conditions are warmer and drier at night under the canopy, which deters rust infection. With an overstory, cooling by outward radiation and dew formation is limited to the upper crown surfaces. Reradiation from the understory pine is reflected back down by the underside of the canopy and warmer night temperatures are maintained in the understory. The overstory may also discourage high densities of Ribes plants.

The overstory shade reduces the daytime temperatures on and around the terminal leaders below the optimum for weevil feeding and oviposition. There is more unsuccessful brood development under shade than in unshaded plantations (Kulman and Harman 1965). Thinner-barked terminal leaders also develop under shade conditions.

The diameter and height of the pines also affect pest susceptibility. Younger trees with small diameters are girdled by rust and die sooner than larger trees. Taller trees with stout leaders are attacked more frequently than shorter trees of the same age (Wilkinson 1981). Trees 2 to 4 feet tall were killed when weevil fed below the lowest living whorl of branches (Kulman and Harman 1967). White pine are more susceptible to pest damage at heights under 22 to 30 feet tall. Severity of damage subsides as trees become 22 to 30 feet tall and crown closure occurs.

Control

The following is a discussion of various control methods to reduce damage from blister rust, weevil and deer.

Blister Rust

The primary methods used to reduce damage by blister rust are planting under an overstory, pathological pruning, eradication of Ribes spp., planting rust resistant stock, and by site selection and stand manipulation.

Planting white pine under an overstory of a light crowned species, such as aspen or birch, will reduce the risk of rust infection. A crown cover of 30 to 50 percent is recommended, which allows for both growth and rust protection. A maximum of 50 percent sunlight is the most practical compromise for seedling growth and pest control (Struik 1977). Overstories should be thin enough so the pines grow more than 2 feet in height each year after the trees are 3 feet tall (Van Arsdel 1979). Thinning the overstory approximately every 5 years will avoid stagnation. The stand density and light intensity should be maintained for the first 20 years, followed by overstory release when the pine are about 25 to 35 feet tall. Underplanting should be on sites with poor value hardwoods, converting marginal hardwood stands to productive pine stands. Understory competition may be severe on sites with fertile soils. Logan (1962) and Clements (1966) found that white pine seedlings can be grown with little reduction in height if the understory is controlled until the seedlings are about 4 feet tall.

Pathological pruning can control rust damage and infection by removing infected branches before the disease reaches the stem and by removing the rust susceptible lower branches before they are infected. Pruning may also limit rust spread (Stewart 1957), and it improves wood quality and value (Horton 1966).

Most of the rust infection of cankers occur on the lower 6 feet of the stem (Hunt 1991 and 1982; Hagle et al 1989; Russell 1988; Van Arsdel 1979). Pruning of the lower rust susceptible branches has been shown to be very effective in reducing damage (Hunt 1991; Hagle and Grasham 1988; Lehrer 1982; Weber 1964). Pruning should start at age 5 to 7, removing the lower one half of the crown, and continuing every 2 years until there are no branches within 8 feet of the ground (Van Arsdel 1979). Delay will increase the incidence of stem cankers dramatically, and little protection is achieved by pruning higher than 8 feet (Hunt 1991). Cankers that appear on the tree at locations other than on the lower branches may be cut out with a knife, however this may only be feasible for trees with very high values.

Guidelines for selecting plantations where pathological pruning to prevent and control rust infection would be appropriate have been developed by Nicholls and Anderson (1977). Depending on the number of crop trees, acceptable annual rates of infection are as follows:

White Pine Per Acre (Number)	Acceptable Annual Lethal Infection (Percent)
200-299	1
300-399	2
400-499	3
500-599	4
600-649	5
650-699	6
700-749	7
750-799	8
800-849	9
850+	10

Control of blister rust by eradication of Ribes was first applied in 1909 (Anderson 1973), and was shown to be effective and economically feasible by Gilbert and Reynolds (1920). Ribes eradication became the largest disease control program ever undertaken, and was assumed to be effective for many decades.

In the 1960's many foresters and researchers began questioning the effectiveness of the eradication program. King (1958) indicated eradication was not economical when the costs were carried forward to crop maturity. In areas with recent fire history, pulling Ribes plants actually resulted in more plants (Stewart 1957).

Ribes eradication can be practical where short distance (less than 100 feet) spread of spores is important, such as much of Zone 3, around nurseries and Christmas tree plantations (Gross 1985), but is ineffective where long distance spread is common, as in most of Zone 4 (Robbins 1984). On the other hand, Van Arsdel et al (1956) and Van Arsdel (1979) stated that even in much of the high hazard zone (Zone 4), eradication reduces the level of pine infection to less than 10 percent.

Todate, the controversy over effectiveness of eradication and research results remains mixed. The width of the protective zone or shape could be important and vary with locality, depending upon the air movement patterns and travel distance of basidiospores. Long distance spore transport, by night air movements, is believed to be the major factor contributing to the failure of eradication to control rust infection on some very high-hazard sites in the northern region (Van Arsdel 1965a, 1965b, 1967). Some Ribes plants may also be missed and a great deal of inoculum can be generated by a few small plants. The ability of Ribes plants to resprout from their roots, if left intact, also contributes to the ineffectiveness of eradication. Banning of 2,4,5-T initially increased the cost of eradication (Scott 1983), but newer herbicides have been developed which are effective.

There has been extensive work devoted to the development of genetic resistance to blister rust by selection and breeding. Genetic resistance to blister rust is present in white pine, and some of the resistant individuals do transmit a degree of resistance to their progeny (Patton and Riker 1966). Apparently six mechanisms of resistance are involved which are: prevention of needle lesions, reduced frequency of such lesions, premature shedding of infected needles, a fungicidal reaction in the short shoot, reactions that eliminate established bark infections and the ability of a seedling to remain alive when infected (Hoff 1986). Breeding has been done to develop a low level, broad based resistance, because the fungus does demonstrate to have pathogenic races (Bingham et al 1971).

Much of the Minnesota breeding program is based on early work by Cliff Algren who selected a large number of white pine that appeared to be rust free from many natural stands. Planting white pine in Minnesota's National Forests has, until recently, been restricted to the use of supposedly rust resistant seedlings. Seeds from trees with putative resistance to blister rust have been produced since 1979 at the Oconto Seed Orchard in Wisconsin, from which nearly 1,000,000 seedlings have been planted on Lake States National Forests (Mielke et al 1990). It is estimated that 25 percent of the seedlings produced since 1983 at Oconto River are potentially resistant to blister rust.

In the past antibiotics have been tested for the control of blister rust with unsatisfactory results (Phelps and Weber; Powers and Stegall 1965; Van Arsdel 1979). Acti-dione (cycloheximide) will kill direct treated cankers, however this method is not considered practical operationally. Phytoactin may stop canker growth for one year, then they resume growth (usually accelerated). Low levels of phytoactin have been shown to stimulate cankers to grow faster. There is no known effective systematic fungicide treatment for blister rust todate.

Site selection is an effective means to control blister rust. Robbins (1984) recommended the following guidelines in site selection, based on soils, climatic, topography, and stand characteristic factors:

Factors	Planting Recommended	Planting Not Recommended
Soils	Loams, sandy loams, loamy sands, or fine sands	Heavy wet soils, soils with a high water table or droughty coarse sands
Climatic	In Zones 1 and 2; In Zone 3 with recommended topography and stand characteristics (see below)	In Zones 4 unless microclimate is appropriate and rust-resistant stock is used
Topography	On steep slopes or hilltops	In topographic depressions or on bases of slopes
Stand Characteristics	Under an overstory; In large forest openings or on old fields (if weevils are not a threat); Close spacing; Use resistant stock, if available.	In small forest openings; Where Ribes is common; In open fields if weevils are not a threat.

Van Arsdel (1979) recommended the following for the best control of blister rust:

"**Zone 1** - For this zone no rust prevention methods are recommended. Some losses will occur at the bases of slopes and in small openings in an overstory crown canopy, but these will not be enough to impair the development of the forest. Small openings in an overstory canopy are those openings in the crowns with a diameter less than the height of the surrounding trees.
Zone 2 - For this moderate-hazard area the following controls are recommended: a.) Eradicate gooseberries and

currants in pine areas and within 70 ft. of the stand or prune the branches from the lower one-half of the crown starting the third year after planting (About age 7) and continuing every two years until there are no branches within 8 ft. of the ground. b.) Avoid planting sites where cold air collects at night and outward infrared radiation continues while in shade. Avoid the bottoms of V-shaped valleys, kettle holes, bases of slopes, small openings in the forest, and selectively logged or shelterwood cut stands. c.) Do plant under solid oak canopies on sandy or dry ridgetop sites, in open fields, on steep slopes, on hilltops and on hill shoulders.

Zone 3 - a. Eradicate or poison Ribes within the pine stands and within 600 ft. of the pines.

b. Prune the lower branches from the lower one-half of the crowns, starting at age 5-7 and continuing every two years until there are no branches within 8 ft. of the ground.

c. Prune out any cankers that appear on the tree at locations other than on the lower branches.

d. Plant only under overstories of aspen, oak on sand or other poor sites, or under lightly thinned birch or pine. In the thinned stands, spaces between the crowns must not exceed one-fourth the height of the surrounding trees. The overstories should be thin enough so the trees grow more than two feet in height each year after the trees are three feet tall.

e. Do not release your pines until they are thirty-five feet tall.

f. Plant only where the Ribes have been eradicated.

Zone 4 - Blister rust spreads long distances in this zone, and losses to blister rust will be greater. Control recommendations are exactly as for zone 3, but you may expect losses to blister rust up to 25 percent (usually less than 10 percent) of your stand, even with the controls. The amount of loss will vary greatly over different parts of zone 4 depending on how many rust spores are being carried into the particular area. Night circulation downdraft areas from counter lake breezes and valley winds will have more rust."

According to Van Arsdel: "In zone 4, of these control methods; eradication alone reduced the number of cankers to 1/8 of those found in the non-eradicated open field site; maintaining an overstory reduced the number of cankers to 1/9 the number found without an overstory; and pruning the trees reduced the number to 1/3 the number of cankers on the unpruned trees."

Weevil

The primary control methods to reduce white pine weevil damage are to plant pine under an overstory, selective pruning and the use of insecticides.

Again, planting white pine under an overstory of a light crowned species, such as aspen or birch, will reduce weevil damage. Berry and Stiell (1979) found there was minimal damage in understory pine where insolation was reduced from 20 to 40 percent of full sunlight. There was little reduction in height growth and thinner leaders were produced where insolation was 35 to 65 percent of full light. Narrow strip plantations, with the adjacent tree canopy excluding greater than 50 percent of full sunlight, may also decrease weevil damage.

Selective pruning of weevil infested terminals may be effective, however this practice may not be economical. It is suggested to prune out and destroy (burn) infested branches as soon as damage is discovered (before mid-July) to kill the insects (Ascerno and Wawrzynski 1988; Benyus 1983; Knight and Heikkenen 1980). One should cut back all but one live lateral shoot, by at least half their length, to maintain single stem dominance. The selection and improvement by pruning of the least injured trees, may prove to be economical and profitable.

Close spacing and high density may increase the chances of obtaining an acceptably stocked stand by rotation age. A close spacing will encourage sooner crown closure, stimulate straight growth with side shade, and the sheer numbers planted may compensate for trees lost to weevils. The removal of less desirable trees from white pine stands for weevil control is also recommended by Baker (1972).

Attempts to locate weevil resistant white pine races or individuals have been unsuccessful, but are continuing (Wilkinson 1981). He suggested planting the more weevil resistant western white pine or hybrids with eastern white pine would be a worthwhile alternative species to eastern white pine.

Insecticide control is recommended if fewer than 250 white pines per acre reach a height of 22 feet undamaged (Kulman 1989). Benyus (1983) suggested drenching tree tops with a registered insecticide as weather warms to control egg-laying weevils. Eggs are usually laid in May. A second treatment between mid-August and late September may be needed to control newly emerged adults. The suggested insecticides are Meta-systox-R, Bendocarb, Oxydemeton-methyl and Lindane. State agencies can place restrictions on the use of these for white pine weevil control. The two insecticides currently used in Minnesota are Meta-systox-R and Bendocarb. The use of Lindane has been banned in Minnesota since 1978. Alfaro et al (1984) has found that pine oil from pulp residue, when sprayed on trees, inhibits weevil feeding in laboratory tests.

Dr. A. Petnaharan of the Pest Management Institute in Sault Ste. Marie has developed new control methods for white pine weevil. He has found that the weevil is active in the field much earlier in spring than formerly believed. This means that spring insecticide application should be shifted to a time coinciding with early weevil emergence. Petnaharan also found that the insect growth regulator Dimilin induces nonviable weevil eggs (Carmean 1990).

Other types of indirect control, such as that exerted by insect parasites and predators and birds, are helpful in preventing excessive high weevil populations, but are incapable of preventing intolerable levels of loss (Baker 1972). Harman and Kulman (1967) published an annotated list of the parasites and predators of the species.

Deer

Many control methods to reduce deer damage have been used in the past with mixed results. Control is difficult due to the mobility of the deer, recent high density populations, and associated control costs.

Protecting seedlings with flexible netting can reduce browse damage to tolerable levels. This netting forms a mesh enclosure (tube) which keeps deer from nipping off buds. Lateral as well as terminal buds may be protected. With an annual maintenance routine of pulling the tube up over the leader, the young trees are able to grow above browse height and gain enough foliage to withstand browse (Paxton n.d.). Frequent maintenance will keep new buds from protruding through the holes in the net, which may deform the tree growth. The deforming which may occur is usually outgrown within a few years (Paxton n.d.). The State Department of Natural Resources (DNR) has used these nets in problem areas with unsatisfactory results. The success of the netting will be affected by the frequency of maintenance and the density and perseverance of the deer population.

Plastic tube treeshelters, such as Tubex, can effectively protect trees against deer browse and buck rub, however this product can be expensive. A four-foot shelter is suggested to deter moderate deer browse and buck rub, five-foot for heavy browse, and a six-foot shelter for extreme browse in heavy snow cover. Experimental use of Tubex with white pine in Aitkin County, by the DNR, has shown that black bears often knocked down and chewed up these treeshelters.

The most effective deer control method, and the most expensive, can be achieved through fence exclosures. A wire mesh fence is effective if it is solidly constructed and at least eight-feet in height. Electric fences are less expensive to build than mesh fences, but they require more maintenance and may be totally ineffective when not electrified.

Most repellents are not suited for large areas due to the high costs, limitations on use, and variable effectiveness. Repellent success is measured in the reduction, not total elimination, of damage. The effectiveness may depend upon rainfall, the availability of other deer browse, and deer perseverance.

Repellents, either repel by taste (contact types) or by odor (area types). Contact repellents are most effective when applied directly to the trees during dormancy. Area repellents are applied near the trees and are usually less effective than contact repellents.

There is a wide range of repellent formulations including, human hair, bone tar oil, ammonium soaps, moth balls, hot pepper sauce, blood meal, fermented egg solids, cat feces, tankage, and Thiram. The more effective repellents are Thiram (Tetra methyl thiuram disulphide), "Deer-Away" ("MGK BGR" putrescent whole egg solids), and "Hinder" (Ammonium soaps of higher fatty acids). A granular form of Thiram is currently being used in containerized seedlings in the State nurseries. The granular form is applied to the soil, taken up through the roots, and incorporated into the trees.

METHODS

Initial Screening Survey

A survey questionnaire was sent to 26 forest management agencies as potential cooperators. The questionnaire requested their cooperation in the survey and to identify the number of white pine stands over five years of age under their management that were regenerated by planting. A list of the potential cooperators originally contacted is shown in Appendix A. Eight agencies responded that they had white pine stands and were willing to cooperate by completing and returning the questionnaire.

The eight agencies were then sent preliminary information survey forms for each stand which requested the following information:

1) agency name, address, phone number and contact person
2) legal description of the plantation
3) distance from summer access road
4) acreage of plantation
5) year established
6) planted, seeded or natural
7) if blister rust resistant stock was used
8) type of site preparation
9) most current stocking information
10) original stocking if planted
11) pest problems such as blister rust, weevil, deer, etc.
12) other comments.

A total of 332 white pine stands (including five stands that were subsequently added) were identified and for which survey forms were completed. Subsequently added stands included four stands from the USFS on the Chippewa National Forest and one stand that was privately owned. One of the stands indicated from the DNR was also privately owned. Table 1 indicates agency response.

Table 1. Agency response.

Agency	Number of White Pine Stands	Percent of Total
Private	2	0.6
County	18	5.4
DNR	249	75.0
USFS	62	18.7
IRRRB	1	0.3
Total	332	100.0

Only plantations were considered for field observation and small experimental plantations were excluded. Eight stands did not meet this criteria.

Selection of Sample Plantations

After some preliminary field observations were conducted, plantations younger than six years and older than twenty-nine years were eliminated from further consideration. It was determined that information from stands of this age would not be useful in meeting the objectives of the survey. The stands that did not meet the age requirements totaled 103. There were also 17 stands that were duplications due to replanting, leaving a total of 204 possible plantations for field observation.

The agency offices were visited as necessary for assistance to locate the plantations, and to gain information from their planting and development records for each stand.

An attempt was made to visit and collect information on all plantations meeting the above criteria. However some were excluded due to inaccessibility, complete plantation failure, nonexistence, or the stand characteristics did not meet the baseline data given by the cooperator or the stand could not be located.

Field observation data was collected on 132 plantations, of which 6 were eliminated due to the age criteria. Thus, 126 plantations were visited, survey forms completed and counted in this survey. This results in 62 percent return of the possible 204 plantations for field observation. The breakdown by agency is shown in Table 2.

Table 2. Plantation survey by agency.

Agency	Number of Possible Plantations	Number of Plantations Counted	Number of Plantations Eliminated
Private	2	2	0
County	13	7	6
DNR	166	109	57
USFS	23	8	15
Total	204	126	78

The location of the 126 plantations which were sampled is shown in Figure 3. Table 3 gives a breakdown by county.

Table 3. Plantation survey by County.

County	Number of Plantations Counted in Survey
Aitkin	1
Carlton	1
Cass	13
Crow Wing	4
Fillmore	14
Goodhue	12
Houston	14
Isanti	1
Itasca	1
Kanabec	1
Koochiching	1
Lake	3
Lake of the Woods	2
Mahnomen	1
Roseau	3
St. Louis	10
Sherburne	2
Wabasha	23
Winona	18
TOTAL	126

Sampling Process

The white pine plantation field survey form and instructions for filling it out is in Appendix B. The tally sheet used is shown in Appendix C.

Acreage, age of plantation since established, use of white pine blister rust resistant stock, and site preparation methods were obtained from the original survey forms or from the cooperators.

The regeneration description (free to grow or suppressed by vegetation) was a subjective judgement made of the entire plantation.

RAND McNALLY LOOSE LEAF OUTLINE MAP MINNESOTA

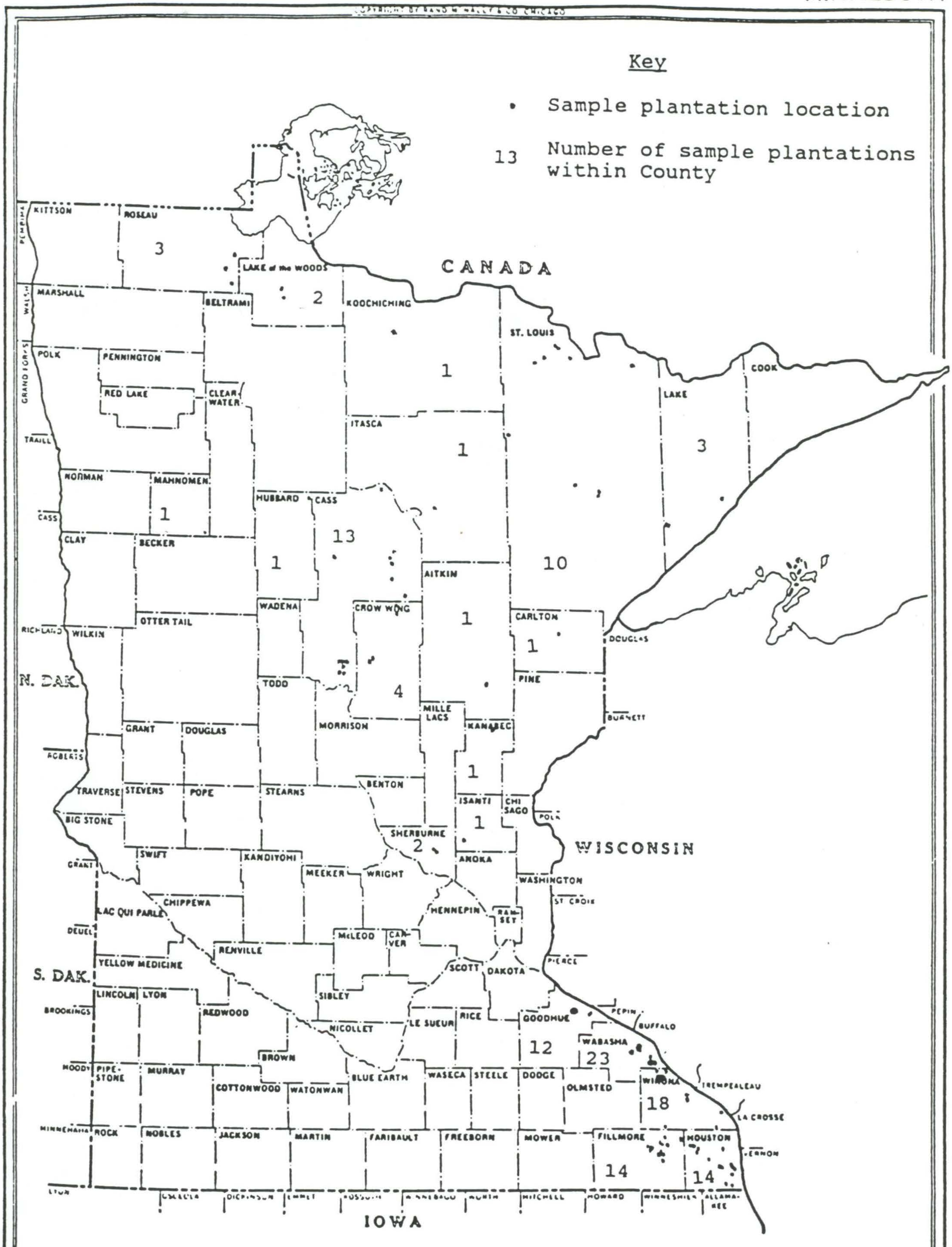

Figure 3. Location of sample plantations.

Site Index was estimated from trees in the stand or in adjacent stands on similar soils when possible. Many stands had development records indicating the site index for the plantation, however, the majority or the development records rated the site quality as good, medium or poor. Site index curves were used when applicable.

Stand averages of height, diameter at breast height (dbh), basal area, and trees per acre of white pine were determined.

Timber stand improvement items were noted. Pruning height to the nearest foot, release method, and date of release were obtained from records or estimated from site visit when applicable.

The topography of the stand was recorded using the following designators:

Designator	Topography Classes
a	slope greater than 10%
b	level ridge top
c	level broad valley
d	level narrow valley
e	level
f	undulating

Aspect was noted when the plantation was located on a slope. If the stand was planted in an old field, it was also indicated.

The species and spacing were noted when the plantation was a mixed planting or when the presence of another species greatly increased the stocking.

The distance from water bodies, lakes greater than

600 acres and lakes less than 600 acres, swamps or potholes, was estimated in miles or feet using maps or site inspection.

Overstory information, such as average height and dbh, was recorded when white pine was planted under an overstory. The basal area of the overstory trees was estimated using a 10 factor prism. The overhead species composition was also noted, and the percent canopy coverage was ocularly estimated.

The understory density classes, (low, medium, high, open, grass) and the percent of plots which contained Ribes was obtained.

Collection of Information

At each stand, one-.01 acre plot per acre, with a minimum of 3 plots and a maximum of 10 plots, was located and observations made as noted above.

The first plot was located one chain from the first white pine observed in the cardinal direction of the majority of the stand. Numbers were selected at random with increments of 5 degrees from 0 to 90 and added or subtracted from the previous bearing to determine the direction of the next plot. Distance between plots varied with stand acreage and configuration.

Plot center was the closest white pine after distance was paced off. The perimeter of the .01 acre circular plot was determined either by tape or by an 11.8

ft. stick.

The number of living white pine regeneration, dead white pine, and other trees that would be considered as regeneration were tallied for each plot. The average height to the nearest foot and the dbh to the nearest inch was estimated for living white pine and other species in each plot.

The percent canopy coverage was ocularly estimated in 10% increments.

Blister rust information was tallied by code for living infected white pines. The code contained 3 to 4 designators. First the height of infection to the nearest foot was entered. Next, the type of infection was recorded, being a stem (S) or a branch (B) canker. Then, if the type of infection was a branch canker, whether it was "lethal" (L) or not was noted. Cankers between 2 and 18 inches from the main stem were considered "lethal". The last designator was the number of white pine infected in the plot. If an entry was 2BL3, this indicated that three trees were infected with lethal branch cankers that occurred 2 feet above the ground.

The number of white pines that had been damaged by white pine weevil and deer in each plot was also tallied. A tree was entered more than once if it had been attacked by more than one pest. The presence of ribes within the plot was also recorded.

The density of the shrub layer was estimated into the following broad categories:

Shrub Density	Approximate Number of Stems Per Milacre
Open	none
Low	1 to 50
Medium	50 to 100
High	100+

The basal area of white pine and other tree species was estimated using a 10 factor prism.

Other tree species present within the stand were noted and comments made.

RESULTS AND DISCUSSION

It should be noted that because of the nonparametric nature of the data, rigid statistical analysis did not apply to this study.

The data was summarized and divided into the following regions: the State as a whole, the Northern counties versus the five Southeast counties, all counties, and Van Arsdels' (1978) blister rust hazard zones. The five counties in the Southeast, Fillmore, Goodhue, Houston, Wabasha and Winona had different damage patterns when compared to the Northern counties, thus the separate division.

A total of 126 stands were visited, with 1016 plots taken, representing 1133 acres (Table 4). In the entire State, 5 percent of all trees tallied (15% of all plots) were infected with blister rust, 9 percent of the trees (14% of plots) were damaged by weevil, and 23 percent of the trees (32% of plots) were damaged by deer. Deer are the most serious damaging agent to white pine in Minnesota.

A total of 51 percent of all stands were infected with blister rust, with a stand infection range of 0 to 43 percent of the trees. Weevil damage was detected in 23 percent of all stands, with a stand damage range of 0 to 100 percent. Deer damage was found in 53 percent of the stands.

Table 4. Damage summary by county, region and blister rust hazard zone.

Location	# of Stands	Total Acres	Trees Tallied	Plots Taken	Blister Rust % of Trees	Blister Rust % of Stands	Weevil % of Trees	Weevil % of Stands	Deer % of Trees	Deer % of Stands
Aitkin	1	8	25	8	0	0	0	0	100	100
Carlton	1	16	21	10	43	100	29	100	95	100
Cass	13	174	430	120	1	15	30	62	50	62
Crow Wing	4	19	77	25	0	0	5	25	47	50
*Fillmore	13	59	295	76	2	23	0	0	16	77
*Goodhue	13	108	362	101	6	54	0	0	0	8
*Houston	14	156	332	118	5	50	0	0	10	57
Hubbard	1	1	15	4	0	0	53	100	0	0
Isanti	1	3	28	10	4	100	29	100	0	0
Itasca	1	6	26	10	0	0	0	0	100	100
Kanabec	1	4	31	4	0	0	0	0	100	100
Koochiching	1	20	20	10	30	100	45	100	95	100
Lake	3	12	66	23	6	67	24	100	85	100
Lake of the Woods	2	14	55	16	11	50	2	50	78	100
Mahnomen	1	5	22	7	0	0	0	0	45	100
Roseau	3	11	79	20	3	33	5	100	81	100
St. Louis	10	119	334	77	7	60	37	70	23	70
Sherburne	2	48	60	20	2	50	12	100	0	0
*Wabasha	23	127	484	205	12	78	0	0	11	22
*Winona	18	223	701	152	5	44	0	0	6	17
North Region	45	460	1289	[illegible]64	4	47	25	64	48	69
Southeast Region	81	673	2174	652	6	53	0	0	8	44
State Total	126	1133	3463	1016	5	51	9	23	23	53
Blister Rust Hazard Zone										
1	49	458	1374	414	7	63	0	0	7	45
2	24	217	660	205	5	46	2	13	8	25
3	29	250	752	214	3	34	15	38	35	69
4	24	208	677	183	5	42	25	63	54	79

* Five counties in Southeast region, remainder of counties are in the North region.

Deer damage by stand ranged from 0 to 100 percent.

The damage patterns in the five county southeast region differed from that in the North. The southeast region had no weevil damage, considerably lower deer damage and slightly higher rust infection when compared to the counties in the north region (Table 4).

The counties with 10 percent or higher of the trees infected with blister rust were; Carlton (43), Koochiching (30), Wabasha (12) and Lake of the Woods (11). Counties with 10 percent or more of the trees with weevil damage were; Hubbard (53), Koochiching (45), St. Louis (37), Cass (30), Carlton (29), Isanti (29), and Lake (24) and Sherburne (12) Counties.

A number of counties had severe deer browse damage. Those with 75 percent or more of the trees with deer damage were; Aitkin (100), Itasca (100), Kanabec (100), Carlton (95), Koochiching (95), Lake (85), Roseau (81) and Lake of the Woods (78) Counties. The combination of the three damaging agents showed that Koochiching and Carlton Counties had the most problems, and Goodhue, Winona, Sherburne, Houston and Fillmore Counties had the least. It should be noted the above results may be biased because of small sample sizes in some of the counties. For example, most of the counties with high damage percentages such as Carlton had only one or two stands that were visited.

In summary, the results indicated that overall deer damage is most serious, followed by weevil, and lastly blister rust. The extent of deer damage on the new growth and terminal leaders also probably reduced the observations of blister rust and weevil incidence, so damage from those sources may be higher than indicated.

The location of the sample stands in relation to Van Arsdel's (1978) blister rust hazard zones is shown in Figure 4. When a stand was located on a zone boundary line, it was placed into the higher numbered zone. A total of 49 stands were in Zone 1, 24 stands in Zone 2, 29 stands in Zone 3 and 24 stands in Zone 4.

Hazard Zone 1, which according to Van Arsdel (1978) is the lowest rust risk zone, had the highest rust infection rate based on this survey with 7 percent of all trees tallied (63% of stands) infected with blister rust. Five percent of the trees (46% of stands), in Zone 2, were infected with rust. The lowest rust infection was found in Zone 3, with 3 percent of the trees (34% of stands) to be infected. Zone 4 had 5 percent of the trees (42% of stands) infected.

The highest blister rust incidence was found in Zone 1, the lowest risk zone. This may be attributed to the low level of weevil and deer damage, and variations in the microclimate due to topography. Zone 1 had no weevil incidence and relatively low deer damage. This increased the availability of foliage for potential infection which may have added to the high incidence of rust in Zone 1.

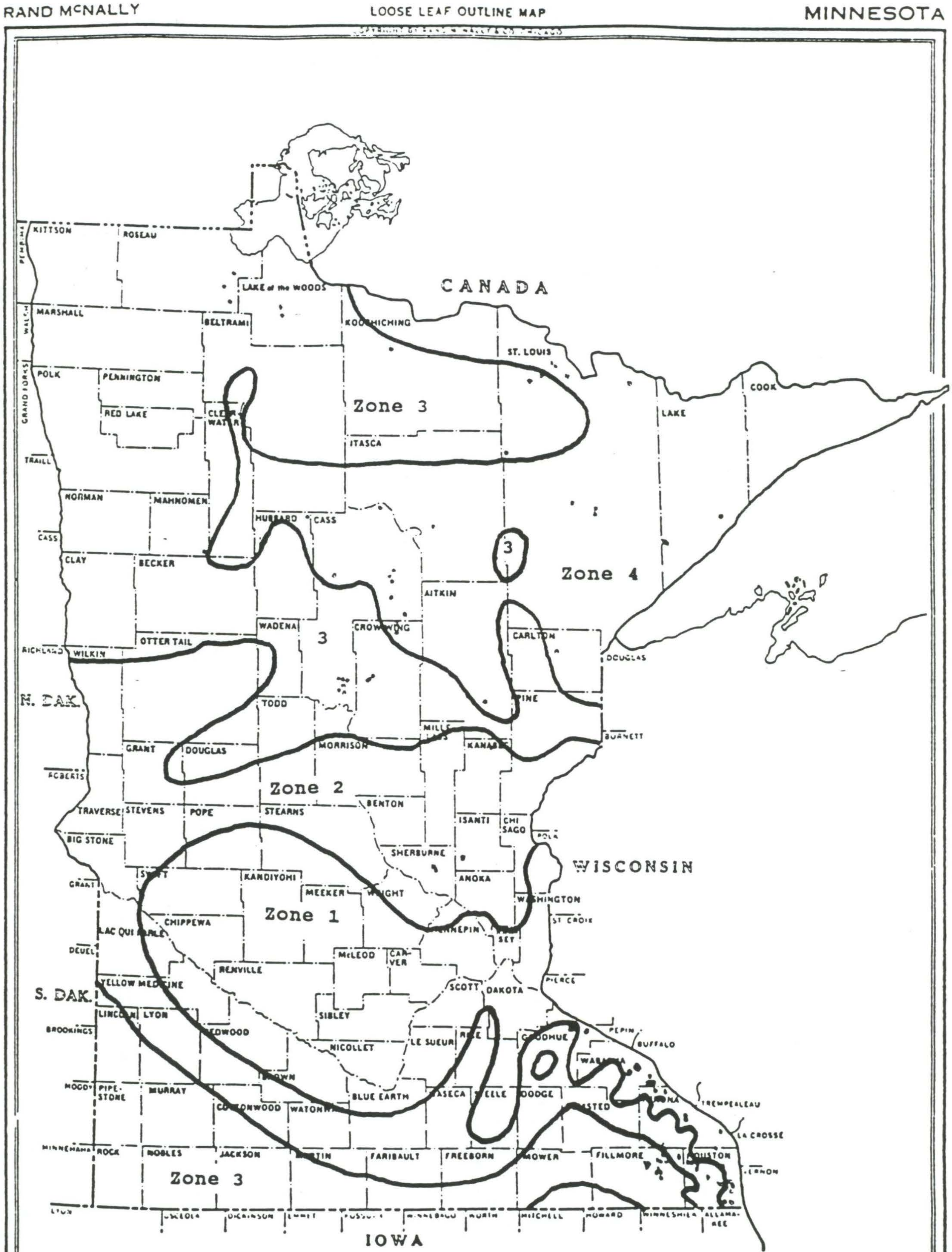

Figure 4. Location of sample plantations with Van Arsdel's (1979) blister rust hazard zones.

In other zones, weevil and deer probably reduced rust the availability of foliage which in turn may have reduced rust observations.

It should also be noted that not all the details of climatic zoning can be shown on the maps in Figures 2 and 8 because of the small scale. Most of the white pine in southeastern Minnesota is planted in old fields on ridge tops. Van Arsdel (1979) states that the highest hills and plateaus in this area should be considered to be in Zone 3. Determination of which plantations were located on the highest hills and plateaus was not done in this survey, and these details were not included in the zoning classifications. However, it seems reasonable, that the classification of many plantations in this area would be subject to consideration for a different classification. For example, many of the plantations classified in Zone 1 might actually be classified in Zone 3. This factor would lower the infection rates in Zone 1 and raise the rust incidence for Zone 3, bringing the rates between zones to what might be expected.

Ribes spp. was present in 17 stands (13.5% of total stands in State), of which 10 stands were infected with blister rust. Eight percent of the trees, in stands with Ribes present, were infected. Of the 28 plots with Ribes, only 3 plots had Ribes and rust incidence. Table 5 shows the percent of stands with

Table 5. Percent of stands with Ribes present and blister rust compared to region averages.

Region Averages	% of Stands[1] (% of trees) w/ WPBR			% of Stands (% of plots) w/ WPBR		
	<	>	=	<	>	=
County	29.4	29.4	41.2	35.3	35.3	29.4
Zone	47.1	41.2	11.7	47.1	52.9	0
No. or SE[2]	52.9	47.1	0	47.1	52.9	0
State	47.1	52.9	0	47.1	52.9	0

[1]% of Stands (% of trees) w/ WPBR = percent of stands infected with white pine blister rust, measured by percent of trees infected.
% of Stands (% of plots) w/ WPBR = percent of stands, infected with white pine blister rust, measured by percent of plots infected.
< = percent of stands having less blister rust than the respective region average.
> = percent of stands having greater blister rust than the respective region average.
= = percent of stands having equal blister rust to the respective region average.
[2]No. or SE = North or Southeast region.

Ribes present and blister rust compared to their respective region averages. This comparison shows no relationship between the presence of Ribes in a stand, when compared to the region averages, and blister rust. Observations recorded of Ribes within stands was low, However, the incidence of Ribes casually observed adjacent to stands was quite high. This is most likely a result of the insufficient sampling. The incidence of Ribes was not adequately determined so any conclusion relating to the amount of blister rust and the incidence of Ribes in that stand is not meaningful.

Blister rust incidence was low when sample stands were within one mile of lakes greater than 600 acres. Table 6 shows that rust infection increased substantially when distance increased beyond one mile. The pattern in the north region showed a steady increase in rust incidence with increased distance. But in the southeast region, rust incidence slowly increased with distance, peaked at 1 to 2 miles, then decreased. The low rust incidence when stands were closer to the lakes is evident when the stands are divided into hazard zones. Plantations in Zone 1 had an extremely high incidence of rust when 1 to 2 miles away from lakes. The incidence decreased at distances greater than that. The high incidence of blister rust in the southeast region, 1 to 2 miles from lakes greater than 600 acres, may be due to the long-distance spore travel by air-movements near the

Table 6. Blister rust with distance from water bodies greater than 600 acres.

	0-1/4 Miles % trees[1] w/ WPBR	0-1/2 Miles % trees w/ WPBR	0-1 Miles % trees w/ WPBR	>1-2 Miles % trees w/ WPBR	>2-5 Miles % trees w/ WPBR	>5-10 Miles % trees w/ WPBR	>10-20 Miles % trees w/ WPBR	>20+ Miles % trees w/ WPBR
Entire State	0.5	0.6	1.3	8.0	5.6	7.9	7.8	3.2
North Region	0	0	0.5	2.4	5.4	7.7	9.4	30.0
SE Region	0.5	1.4	3.0	15.3	13.9	8.1	6.0	1.6
Hazard Zone								
1	0.5	1.4	3.0	42.9	5.7	9.3	-	-
2	-	-	-	-	5.7	1.1	9.4	-
3	0	0	0	4.4	5.3	-	6.0	3.9
4	0	0	0.6	0	11.4	10.2	-	-

[1]% Trees w/ WPBR = percent of all trees within a region and distance class infected with white pine blister rust.

Mississippi River Valley. There was no apparent relationship between height of infection in the trees and distance from water.

White pine in the southeast region grew approximately twice as fast than in the north region, for the first 20 years Table 7). However, the growth rates between the regions are about equal after 24 years. The delay in growth of trees in the north region, may be due to suppression by weevil and deer. In the north region, 83 percent of the branch cankers (81 % of the stem cankers) observed were in trees less than 12 years old since establishment. The incidence of branch cankers was highest in the 9- to 11-year-old class. The 18 to 20 age class had the highest occurrence of stem cankers.

Blister rust in the southeast region was distributed among age classes to a greater extent than in the North. Eighty-three percent of the branch cankers observed were in trees less than 21 years old, and 77 percent of stem cankers occurred before age 27. The highest incidence of blister rust and branch cankers was found in the 15 to 17 age class. The 15- to 17- year-old plantations also had a high incidence of stem cankers, but the highest was observed in the 27 to 29 age class.

Deer damage was very high in the 6 to 8 year old stands, with 70 percent of the trees damaged in the north region and 18 percent in the southeast region. Ninety-one percent of all deer damaged trees in the north region

Table 7. Damage comparision with age by region.

Age	$\bar{X}$ HT.' [1]	$\bar{X}$ DBH"	% Trees w/ WPBR	% Trees w/ Branch	% Trees w/Stem	% Trees w/ WPW	% Trees w/Deer
North Region							
6-8	3.4	0.6	2.6	1.3	1.3	6.9	70.1
9-11	8.5	1.1	12.7	9.5	3.2	47.4	24.7
12-14	-	-	-	-	-	-	-
15-17	16.0	3.6	0	0	0	11.5	0
18-20	14.8	3.3	10.6	5.9	4.7	62.4	8.2
21-23	-	-	-	-	-	-	-
24-26	36.3	7.7	1.3	1.3	0	79.0	0
27-29	41.3	7.5	0	0	0	52.5	0
Southeast Region							
6-8	8.3	1.1	2.4	2.0	0.4	0	18.1
9-11	15.4	2.8	9.6	7.6	2.0	0	11.1
12-14	23.0	4.1	4.3	3.2	1.1	0	4.3
15-17	27.3	6.5	16.8	8.4	8.4	0	8.4
18-20	31.3	7.1	8.2	6.0	2.2	0	1.7
21-23	39.0	7.4	2.5	0.2	2.0	0	0.5
24-26	39.7	8.1	0.6	0	0.6	0	2.4
27-29	37.4	7.5	11.4	0.9	10.5	0	0.9

[1] $\bar{X}$ HT. = average height, in feet, of all trees within a region and age class.

$\bar{X}$ DBH = average diameter, in inches, at breast height of all trees within a region and age class.

% Trees w/ WPBR = percent of all trees within a region and age class infected with white pine blister rust.

% Trees w/ Branch = percent of all trees within a region and age class infected with blister rust branch cankers.

% Trees w/ Stem = percent of all trees within a region and age class infected with blister rust stem cankers.

% Trees w/ WPW = percent of all trees within a region and age class damaged by white pine weevil.

occurred before 9 years of age. In the southeast region, 73 percent occurred before age 12.

Overall, blister rust was highest on level ridge tops and slopes, and lowest in the other topographic classes (Table 8). The lowest occurrence of blister rust was on level narrow valleys, however this class was poorly represented in the survey with only three stands.

Rust and weevil damage, in the north region, affected a higher percentage of trees in sites with undulating topography. The high percent of stands with damage on level topography may be biased due to the higher percent of survey plots in this class.

White pine, in the southeast region, showed no incidence of weevil damage. Rust was markedly higher in sites that were located on level ridge tops and on slopes greater than 10 percent. These two topography classes was where most of the plantations were located, and where the pine are most vulnerable to rust.

Table 9 shows the damage comparison with topography by blister rust hazard zone. In Zone 1, 11 percent of the trees and 82 percent of the stands on level ridge tops were infected with rust. Plantations on a slope had 7 percent of the trees infected. The remainder of the topography classes were much lower.

The highest incidence of blister rust in Zone 2 was in sites on a slope (10% of trees infected). The other topography classes had considerably less rust infection

Table 8. Damage comparision with topography by region.

Topography	% Trees[1] w/ WPBR	% Trees w/ WPW	% Stands w/ WPBR	% Stands w/WPW	# of Stands
Entire State					
Slope[2]	5.7	4.9	54.8	9.7	31
L.Ridge	7.8	0	61.3	0	31
L.B.Valley	4.3	0	40.0	0	5
L.N.Valley	1.6	0	33.3	0	3
Level	4.2	15.8	38.3	46.8	47
Undulating	3.7	23.8	22.2	44.4	9
North Region					
Slope	2.8	19.4	50.0	50.0	6
L.Ridge	-	-	-	-	0
L.B.Valley	-	-	-	-	0
L.N.Valley	-	-	-	-	0
Level	4.9	24.7	37.5	68.8	32
Undulating	7.3	52.0	14.3	57.1	7
Southeast Region					
Slope	6.7	0	56.0	0	25
L.Ridge	7.8	0	61.3	0	31
L.B.Valley	4.3	0	40.0	0	5
L.N.Valley	1.6	0	33.3	0	3
Level	3.0	0	40.0	0	15
Undulating	2.2	0	50.0	0	2

[1]w/ WPBR = with white pine blister rust.
w/ WPW = with white pine weevil.
[2]Slope = on slope greater than 10%.
L.Ridge = level ridge.
L.B.Valley = level broad valley.
L.N.Valley = level narrow valley.

Table 9. Damage comparision with topography by blister rust hazard zone.

Topography	% Trees[1] w/ WPBR	% Trees w/ WPW	% Stands w/ WPBR	% Stands w/ WPW	# of Stands
Zone 1					
Slope[2]	7.0	0	60.0	0	20
L.Ridge	10.9	0	82.4	0	17
L.B.Valley	4.4	0	33.3	0	3
L.N.Valley	2.2	0	50.0	0	2
Level	1.1	0	40.0	0	5
Undulating	2.2	0	50.0	0	2
Zone 2					
Slope	10.2	0	50.0	0	2
L.Ridge	3.6	0	37.5	0	8
L.B.Valley	4.1	0	50.0	0	2
L.N.Valley	0	0	0	0	1
Level	4.1	3.2	54.6	27.3	11
Undulating	-	-	-	-	0
Zone 3					
Slope	1.0	10.3	33.3	16.7	6
L.Ridge	3.2	0	33.3	0	6
L.B.Valley	-	-	-	-	0
L.N.Valley	-	-	-	-	0
Level	5.7	16.0	28.6	50.0	14
Undulating	0	56.3	0	100.0	3
Zone 4					
Slope	4.8	22.4	66.7	66.7	3
L.Ridge	-	-	-	-	0
L.B.Valley	-	-	-	-	0
L.N.Valley	-	-	-	-	0
Level	4.4	31.0	35.3	70.6	17
Undulating	7.5	5.0	25.0	25.0	4

[1]w/ WPBR = with white pine blister rust.
w/ WPW = with white pine weevil.
[2]Slope = on slope greater than 10%.
L.Ridge = level ridge.
L.B.Valley = level broad valley.
L.N.V [illegible]

than the slopes. The only stands, within Zone 2 with weevil damage, were in the north region on level ground.

Within Zone 3, the highest rust incidence (% of trees) was on level topography and the most weevil damage occurred in an undulating landscape. In zone 4 most of the weevil damage occurred on level and undulating topography but this is where 88 percent of the stands were located.

The damage comparison with aspect of slopes by region is shown in Table 10. No conclusions with damage and aspect in the north region were made due to the small number of stands sampled that were classified as having aspect. In the southeast region, however, east-facing slopes (east, northeast and southeast) had a higher incidence of blister rust when compared to the other slopes. This is contrary to the literature where west-facing slopes are most prone to rust damage. Southwest-facing slopes also had high incidence of rust.

Control measures such as underplanting and early pruning of the lower branches substantially reduced blister rust infection. Eleven out of the twelve underplanted stands (92%) had no incidence of rust, and 83 percent had no weevil damage. No underplanted stands had trees with stem cankers. Table 11 shows that 100 percent of the underplanted stands had rust infection less than or equal to all region averages.

Table 10. Damage comparision with aspect by region.

Aspect	% trees[1] w/ WPBR	% trees w/ WPW	% stands w/ WPBR	% stands w/ WPW	# of stands
North Region					
N	0	0	0	0	1
NE	5.1	28.2	100.0	100.0	1
E	-	-	-	-	0
SE	5.0	100.0	100.0	100.0	1
S	0	0	0	0	1
SW	8.0	24.4	100.0	100.0	1
W	-	-	-	-	0
NW	0	0	0	0	1
Southeast Region					
N	2.5	0	50.0	0	2
NE	10.8	0	80.0	0	5
E	14.3	0	100.0	0	1
SE	9.9	0	100.0	0	1
S	0.7	0	20.0	0	5
SW	11.8	0	33.3	0	3
W	7.1	0	80.0	0	5
NW	1.4	0	33.3	0	3
Southeast Region					
N[2]	5.8	0	60.0	0	10
E	10.7	0	85.7	0	7
S	6.6	0	33.3	0	9
W	7.5	0	54.5	0	11

[1]% Trees w/ WPBR = percent of all trees within the region and aspect class that are infected with white pine blister rust.
% Trees w/ WPW = percent of all trees within the region and aspect class that are damaged by white pine weevil.
% Stands w/ WPBR = percent of all stands within the region and aspect class that are infected with white pine blister rust.
% Stands w/ WPW = percent of all stands within the region and aspect class that are damaged by white pine weevil.
# of Stans = number of all stands within the region and aspect class.
[2]N = north, northeast and northwest-facing slopes.

Table 11. Percent of 12 underplanted stands with damage compared to region averages.

Region Averages	Total Blister Rust			Stem Canker			Branch Canker			Total Weevil			Total Deer		
	<	>	=[1]	<	>	=	<	>	=	<	>	=	<	>	=
Zone	100	0	0	100	0	0	92	8	0	92	8	0	67	33	0
County	58	0	42	50	0	50	58	0	42	67	0	33	33	42	25
No. or SE	100	0	0	100	0	0	92	8	0	83	8	8	58	42	0
State	100	0	0	100	0	0	92	8	0	83	17	0	33	67	0

[1] < = percent of underplanted stands that had less damage when compared to region averages, measured by % of trees damaged within each stand.

> = percent of underplanted stands that had greater damage when compared to region averages, measured by % of trees damaged within each stand.

= = percent of underplanted stands that had equal damage when compared to region averages, measured by % of damaged trees within each stand.

Weevil damage was considerably lower in underplanted stands when compared to region averages. Ninety-two percent of the stands had less weevil damage when compared to zone averages, 83 percent had less compared to State and north region, and 100 percent had less or equal damage than county averages. It should be noted that underplanted trees were not generally more susceptible to deer browse.

Pathological pruning of the lower rust susceptible branches was effective in reducing blister rust incidence. Thirteen out of the eighteen pruned stands (72%) had no incidence of blister rust. The average pruning height of the stands was 9 feet. There were no lethal branch cankers observed in pruned stands, and only two stands had non-lethal branch cankers. But pruning of the lower branches also reduces the possibilities of observing rust infections. However, 15 out of the 18 pruned stands (83%) had no stem cankers. Table 12 shows the percent of pruned stands and damage compared to region averages. Seventy-eight to 89 percent of the stands had less rust incidence when compared to region averages. Eighty-three to 96 percent of the stands had incidence of stem cankers less than or equal to region averages.

In the entire State, 98.4 percent of all blister rust infection occurred below 9 feet in height on white pine. The range in height of infection was between 0.5

Table 12. Percent of 18 pruned stands with damage compared to region averages.

Region Averages	Total Blister Rust[1]			Stem Canker			Branch Canker			Lethal Branch			Non-lethal Branch		
	<	>	=	<	>	=	<	>	=	<	>	=	<	>	=
County	78	11	11	50	6	44	83	6	11	61	0	39	83	6	11
Zone	78	22	0	83	17	0	94	6	0	100	0	0	94	6	0
No. or SE	89	11	0	83	11	6	94	6	0	100	0	0	89	11	0
State	78	17	6	83	17	0	94	6	0	100	0	0	89	11	0

[1] < = percent of pruned stands that had less damage when compared to region averages, measured by % of trees damaged within each stand.
> = percent of pruned stands that had greater damage when compared to region averages, measured by % of trees damaged within each stand.
= = percent of pruned stands that had equal damage when compared to region averages, measured by % of damaged trees within each stand.

and 16 feet, with an average of 2.8 feet. Only two trees were infected at 16 feet, one at 10 feet, with the remainder below 9 feet.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The salient conclusions gained from this survey are:

1) Deer browse is the most damaging agent to the establishment of white pine plantations in Minnesota.
2) Deer browse is much more serious in the north region than in the five county southeast region.
3) The incidence of blister rust is greater in the southeast region than in the north region.
4) Observations of rust and weevil, in the north region, were reduced by the intensity and extent of deer browse. This may have masked some of the data.
5) No weevil damage was observed in the southeast region.
6) Hazard Zone 1 had the highest incidence of rust, while Zone 3 had the lowest (without regard to microclimatic variances not shown on Van Arsdels' 1978 map).
7) Presence of Ribes within a stand was not correlated with greater incidence of rust. However, as noted earlier, the low sampling intensity of presence or absence of Ribes may invalidate this conclusion.

8) Rust incidence was lowest when a plantation was within one mile of a lake greater than 600 acres. In the north region, rust increased with distance, in the southeast region rust incidence was highest at 1 to 2 miles away then decreased.

9) White pine in the southeast region grew twice as fast than in the north region for the first 20 years, but after that growth was similar. This difference in growth was attributed to the severity of deer browse and weevil in the north region.

10) In the north region, 83 percent of the rust branch cankers and 81 percent of stem cankers observed were in plantations less than 12 years old.

11) In the southeast region the highest incidence of rust branch cankers occurred between the ages of 15 and 17. In the north region the highest incidence of branch canker was between 9 and 11 years.

12) In the southeast region, the level ridge top topography class had the highest incidence of blister rust. In the north region, undulating topography had the highest incidence of both rust and weevil.

13) In the southeast region, east-facing slopes had the highest incidence of observed rust.

14) Underplanting substantially reduced rust and weevil incidence.

15) Pathological pruning substantially reduced blister

rust and stem canker occurrence.

16) Most of the rust infections (98.4%) occurred below 9 feet in height.

Recommendations

Site selection for white pine plantations is a very important factor to successful establishment of white pine. Research has shown that soils, climatic conditions, topography, and stand characteristics are important considerations in selecting sites for planting white pine (Robbins 1984). These survey results support that premise.

Soils to avoid are heavy wet clayey soils, soils with a hardpan or water table within 3 feet of the surface, and droughty coarse sands. One should also avoid very fertile loam soils which may have a high degree of woody competition.

There are many microclimatic variations within blister rust hazard zones or regions. If climatic conditions and site selection is given careful consideration, there are many opportunities for plantation success within high risk zones.

This survey showed less risk of rust infection when a plantation is within one mile of a lake greater than 600 acres. In the north region, rust incidence increased with increased distance from a large lake. Plantations in the southeast region had the highest rust incidence between one and two miles away, then rust incidence decreased with distance. This indicates that planting of white pine in the southeast region (especially in Zone 1) when within one to two miles from a lake greater than 600 acres should be avoided without careful consideration of microsite selection..

Topography is a factor that greatly affects the microclimate conditions. Planting in depressions and at bases of slopes where cool air collects should be avoided. In the north region, planting on level topography had the least pest problems and undulating topography had the highest rust and weevil problems. One should avoid planting on high ridge tops in the southeast region (especially in Zone 1) to reduce rust incidence. Again in the southeast region, one should avoid planting on east, northeast, southeast, and southwest-facing slopes.

Stand characteristics also influence pest damage. Planting in small openings should be avoided. A small opening in an overstory canopy are those openings in the crowns with a diameter less than the height of the surrounding trees. Large open plantations in the north region are susceptible to weevil damage and pruning may be necessary.

Underplanting white pine with a light overstory reduces rust and weevil damage and will not increase deer damage according to this survey. This is recommended in all areas of the State where weevil and rust damage is likely to occur. The recommended canopy cover of 30 to 50 percent should be maintained for the first 20 years, followed by overstory release when the white pine are about 25 feet tall. Plan to thin the overstory approximately every five years to avoid stagnation.

Pathological pruning of the rust susceptible lower branches will reduce rust infection. Begin removing the lower half of the crown, before the plantation is 6 years old, and continue every 2 years until there is 8 feet of branchless bole from the ground. Pruning is recommended for all areas of the State where there is a high incidence of rust. Pruning may not be necessary in underplantings.

Site selection is also very important when planting blister rust resistant seedlings. Resistant seedlings are not necessarily immune to rust. The use of resistant stock is recommended in all areas of the State especially where rust incidence is high.

The literature suggests that Ribes eradication is an effective and efficient means to reduce losses to blister rust. It is recommended that all Ribes be eradicated within 70 feet of a plantation in Zones 1 and 2, and within 600 feet in Zones 3 and 4.

The final recommendation is to implement some economically effective means of deer control. Deer damage decreases after the white pine is 11 years old or taller than 9 feet. White pine in the north region may, however, show a higher incidence of rust and weevil damage after deer browse is lessened.

Many of the recommendations above are similar to or were taken from Van Arsdel (1979) and Robbins (1984).

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APPENDIX A

List of potential survey cooperators.

Aitkin County
Becker County
Beltrami County
Blandin Paper Company
Boise Cascade
Bureau of Indian Affairs
Carlton County
Cass County
Champion Int'l Corporation
Chippewa National Forest
Clearwater County
Cloquet Forestry Center
Crow Wing County
Hedstrom Lumber Co.
Hubbard County
IRRRB
Itasca County
Koochiching County
Lake County
Minnesota DNR
NCFES
Pine County
Potlatch Corporation
Rajala Timber Co.
St. Louis County
Superior National Forest

APPENDIX B

Instructions for white pine plantation survey form

1. Site #, agency, county, contact person, phone, legal - information taken from original cooperator survey forms

2. Stand Information

   a. acres, age, WPBR (white pine blister rust resistant stock used when planted), site prep - taken from original forms or obtained from cooperator

   b. TPA - trees per acre when planted from original forms

   c. Regeneration description - a general comment based on overall stand condition at the time of visit, whether the white pine are free-to-grow or suppressed by vegetation

   d. SI - site index, taken from trees on plot, in adjacent stands on similar soil type or from site index curves

   e. Avg ht, avg dbh, Ba, trees/acre - use averages obtained from plot inventory

   f. TSI - indicate if pruned and to what height, indicate if released, when and what method - take from records of from site visit

   g. Topography - indicate general topography of the stand by circling the appropriate letter, slope=greater than 10%

   h. Aspect - north, south, east, west or N/A (not applicable)

   i. Old field - if an old field planting, so indicate

   j. Mixed stand - indicate if stand is mixed, with what species and the spacing

   k. Distance from lake - put estimated distance in feet or miles as appropriate based on maps or site inspection

   l. Overstory - average height and dbh of species in overhead canopy based on plot inventory, estimate BA with 10 factor prism also list species present and percent canopy

APPENDIX B (Cont.)

m. Understory - use plot inventory and circle the appropriate term

n. Ribes - indicate percent of plots with Ribes present based on plot inventory

3. Plot information - use .01 acre plots with a radius of 11.8 ft, take one plot per acre with a minimum of three and a maximum of ten in any given stand; locate first plot one chain from the first white pine observed in the cardinal direction of the majority of the stand; select at random, with increments of five degrees from 0 to 90, and add or subtract from the previous bearing to determine the direction of the next plot; distance between plots will vary by stand acreage and configuration

   Tally the following information on each plot:

   a. Count the number of living white pine regeneration

   b. Count the number of dead white pine, try to determine cause of mortality and enter as a code on the tally sheet

   c. Count the number of other trees on the plot that would be considered as regeneration

   d. ocularly estimate dbh and height of living white pine and other species

   e. Estimate the % overhead canopy, if none enter zero

   f. Count the number of living white pine that are currently infected with blister rust, have been weeviled, or deer browsed, a tree may be counted more than once if it has been attacked by more than one pest

   g. Indicate blister rust infections as either branch or stem cankers and height of infection; if branch indicate if canker is "lethal" (2-18 in. from stem) or "non-lethal" (greater than 18 in. from stem)

   h. Indicate the presence or absence of Ribes on plot

APPENDIX B (Cont.)

i. Estimate the density of the shrub layer by the following broad categories:

Shrub Density	Approx. # of Stems/milacre
Open	**none**
Low	**1 to 50**
Medium	**50 to 100**
High	**100+**

j. fill in information on bottom of form

Before departing from the stand write any comments that might be necessary to fully describe the stand condition on the back of form.

APPENDIX C

WHITE PINE PLANTATION SURVEY

Site # _____ Agency __________________ County ____________________

Contact Person ______________________________ Phone ________________

Legal: R____ T____ Sec____ 40______ Other______________________ Zone _______

Stand Information

Acres_______ Age _____ WPBR _______ Site Prep _____________________

White Pine: Regen Descrpt: free to grow, suppressed

SI _____ Avg Ht ______ Avg Dbh ______ BA ______ TPA ________

TSI: Pruning height _____ Release ____ Year _____ Method ____________

Topo: a* b c d e f Aspect ________ Old Field ______

Mixed Stand ____ Species __________ Spacing _________

Dist from lake > 600 ac: __________ Dist from lake < 600 ac, swamp or pothole __________

Overstory: Avg Ht _____ Avg Dbh ______ BA ______

Composition _____________________________________ % Canopy________

Understory: density low, med, high, open, grass Ribes ? __________

Plot Information

Plot #	# WP Alive	# WP Dead	# Other	$\bar{x}$ dbh WP	$\bar{x}$ dbh Other	$\bar{x}$ ht WP	$\bar{x}$ ht Other	% Canopy	# WP w/BR	# WP w/wpw	# wp w/deer	# Ribes	Shrubs L-M-H-O	BA WP	BA OTR
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
Tot															
Avg															

Other tree species present ____

Comments:____

* a.on slope b.lev ridge c.lev broad val d.lev nar val e.level f.undul